DE LA RECHERCHE À L'INDUSTRIE

Cryogenic Lines

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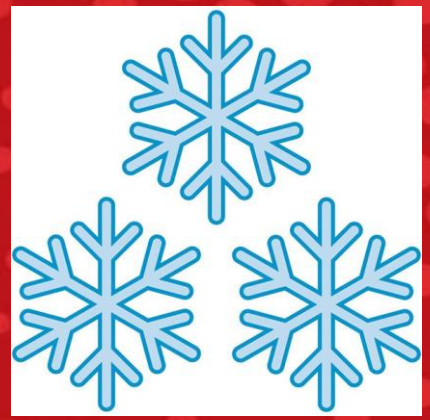
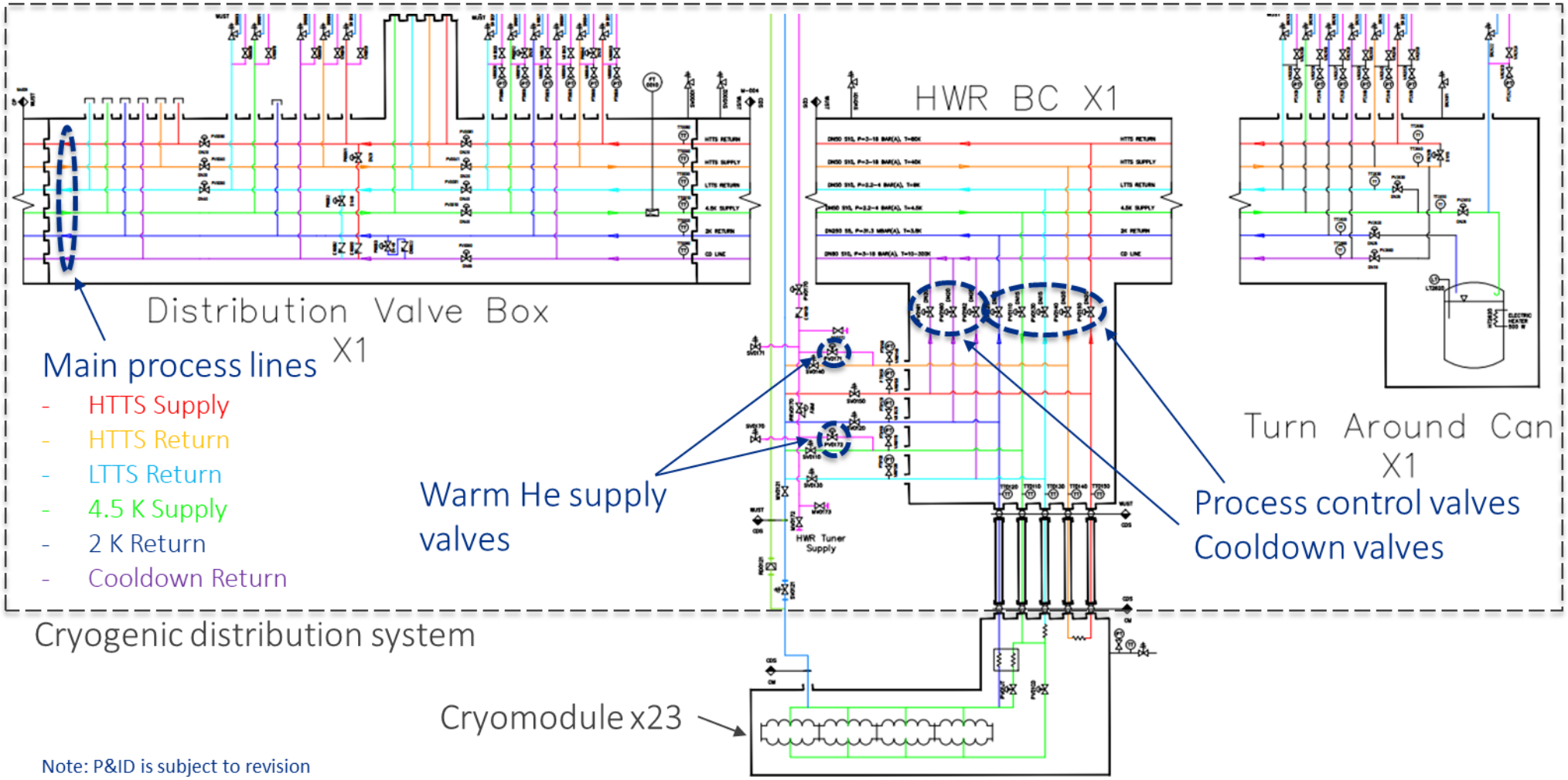
Outline

- Interfaces with the Cryogenic Distribution System (CDS)
- Cool down process
- Maximum Allowable Working Pressure (MAWP)
- Licensing
- Description of the cryogenic lines



Cool Down of the Cryomodule

Cryogenic Distribution System (CDS) Overview



From the presentation «CDS procedures for CM cooldown/warmup», PIP-II Cryogenic Integrated Workshop, February 2021

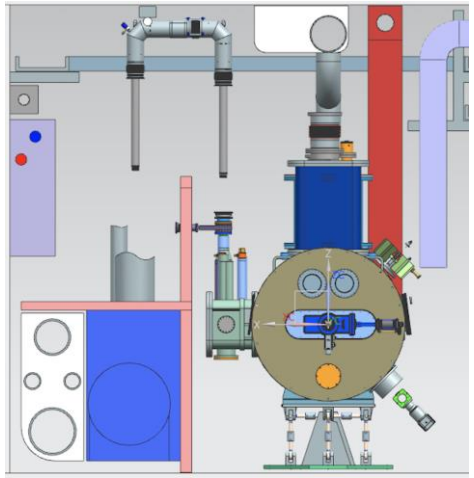
Parameters of the CDS

Type of process	Process Line	Temp. (K)	Pipe Size	Nom. Pressure (bara)
Main process lines	2 K Return	3.8	DN250	3.1 x 10-3
	4.5 K Supply	4.5	DN50	2.9
	LTTS Return	9	DN50	2.9
	HTTS Supply	40	DN50	18
	HTTS Return	80	DN50	18
	CD Return	80	DN80	18
Branch process lines	2 K Return	3.8	DN65	3.1 x 10-3
	4.5 K Supply	4.5	DN15	2.9
	LTTS Return	9	DN15	2.9
	HTTS Supply	40	DN20	18
	HTTS Return	80	DN20	18
	CD Return from HTTS Return	80	DN20	18
	CD Return from 2 K Return	80	DN20	18
	CD Return from LTTS Return	80	DN20	18

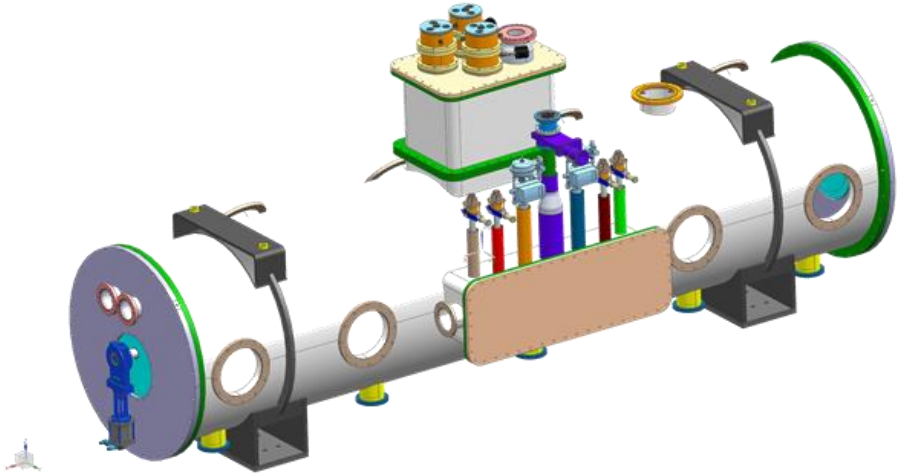
From the presentation «PIP-II CDS Pressure drop and Mass Flow Analysis», PIP-II Technical Workshop, December 2020

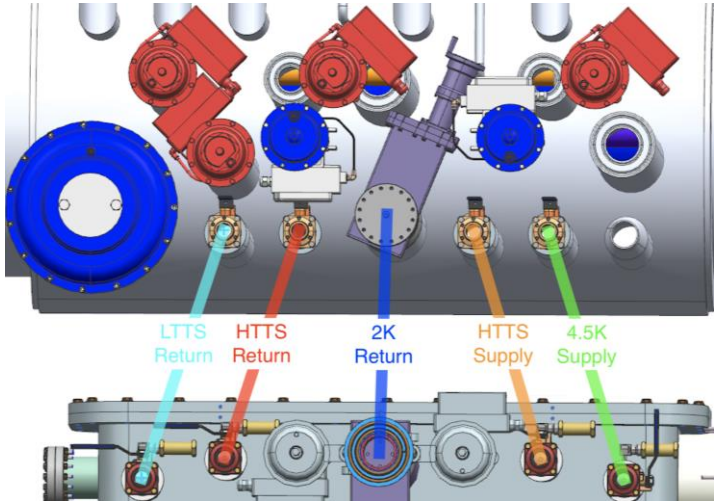
Interfaces between CDS and LB650 Cryomodule

- Connection between the CDS and the cryomodule thanks to U tubes. These ones have bellows to give flexibility.



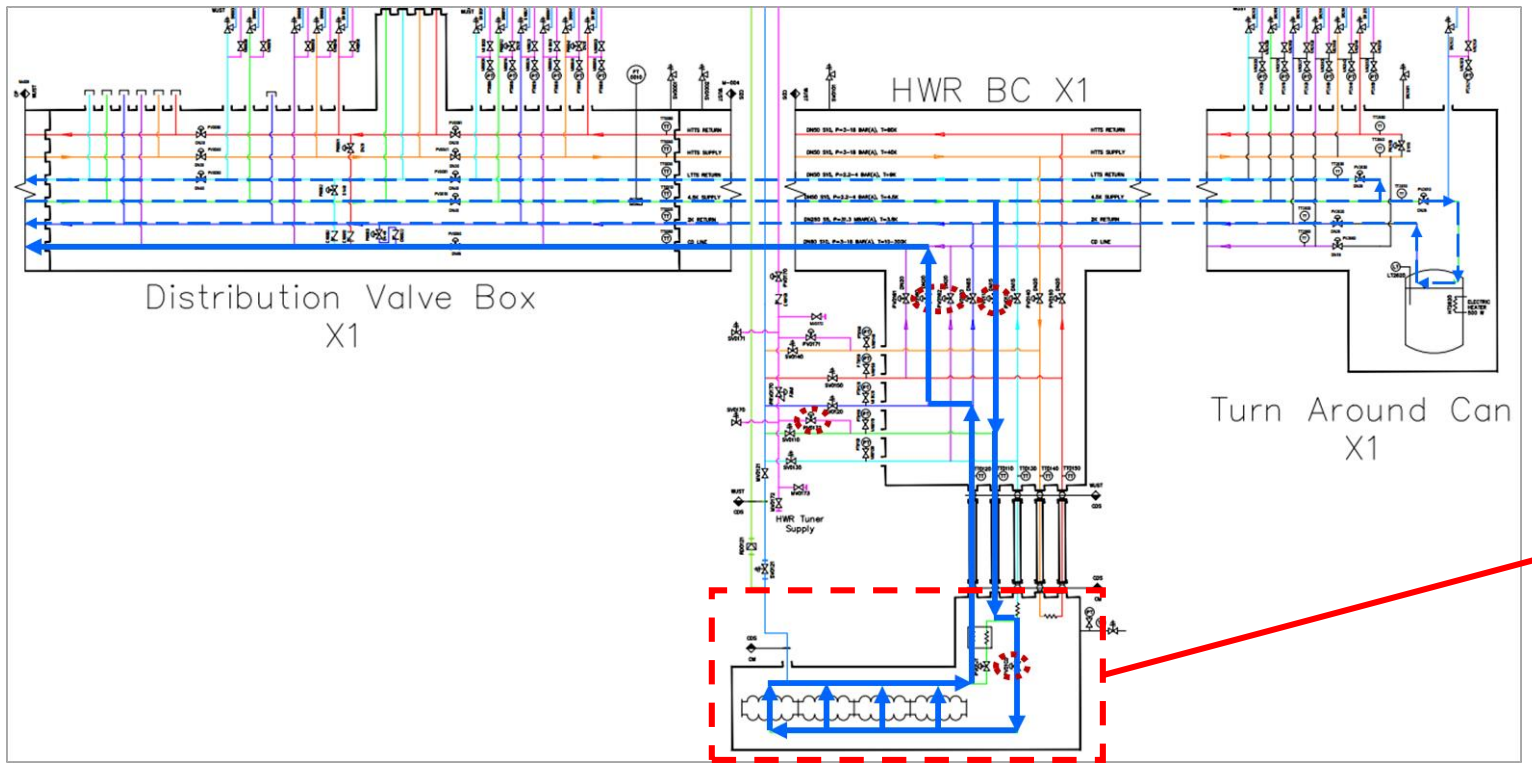
- Cryogenic side port on the cryomodule which includes the 5K bayonets (“*4.5 K Supply*”, “*LTTS Return*”), the 50K bayonets (“*HTTS Supply*”, “*HTTS Return*”), the 2K bayonet, the cool-down and Joule-Thomson valves.

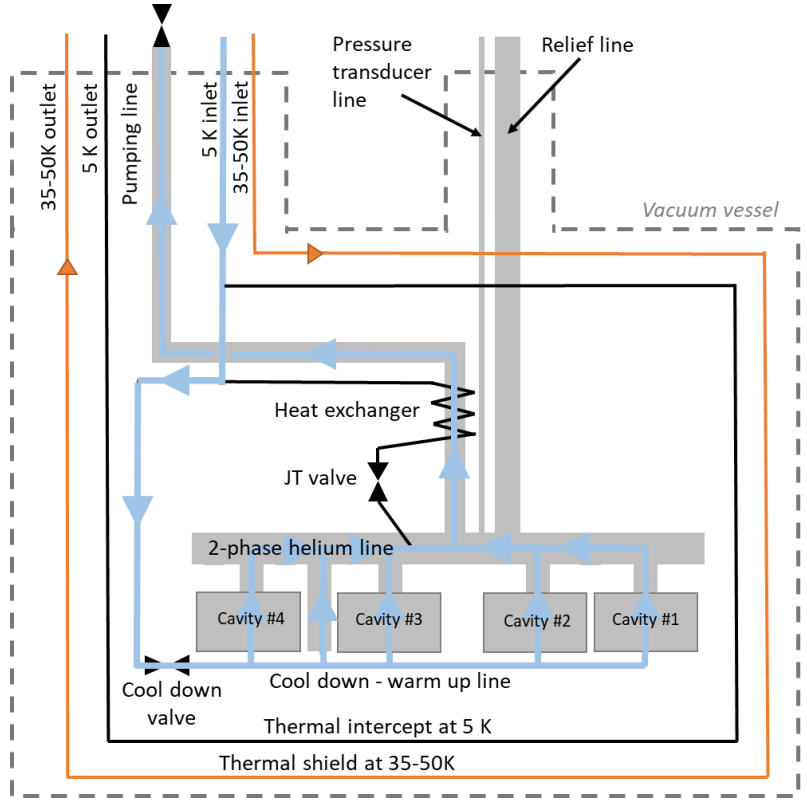




Cool down of the cavity string to 5 K

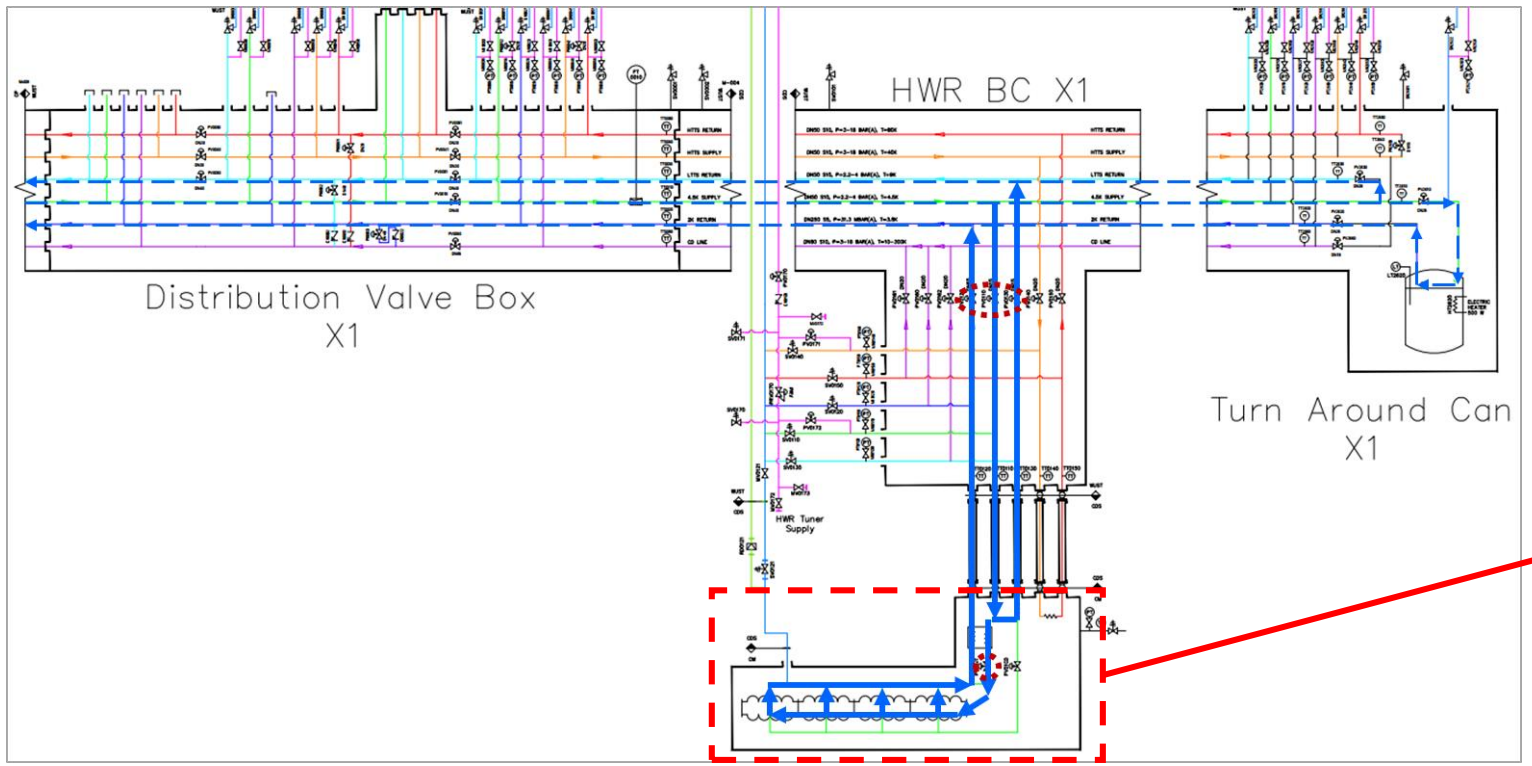
- Possible mixture of liquid and warm helium gas to respect the cool-down requirements.
- Pressure at the inlet of the cavity circuit: 2.9 bara (before the cool-down valve).
- Pressure in the cavities: XXX bara (after the cool-down valve).
- Helium gas return through the pumping line outlet, sent back to the cryoplant through the "*CD line*".

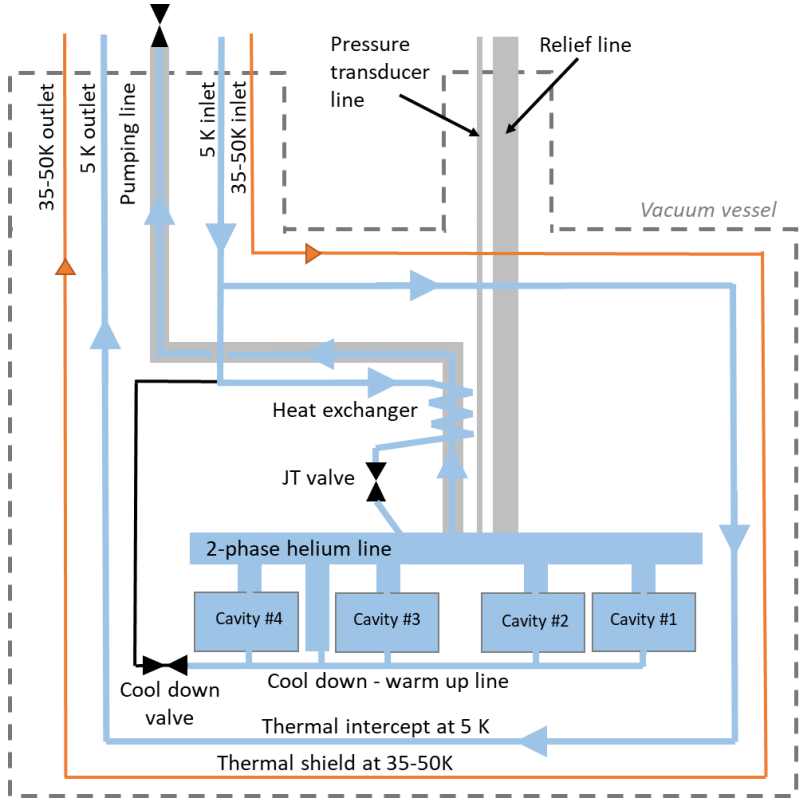




Nominal operation

- 2 K pumpdown in the cavities (pressure ~30 mbar).
- 5 K liquid helium at 2.9 bara flowing in the thermal intercept line.
- Cool-down valve closed.

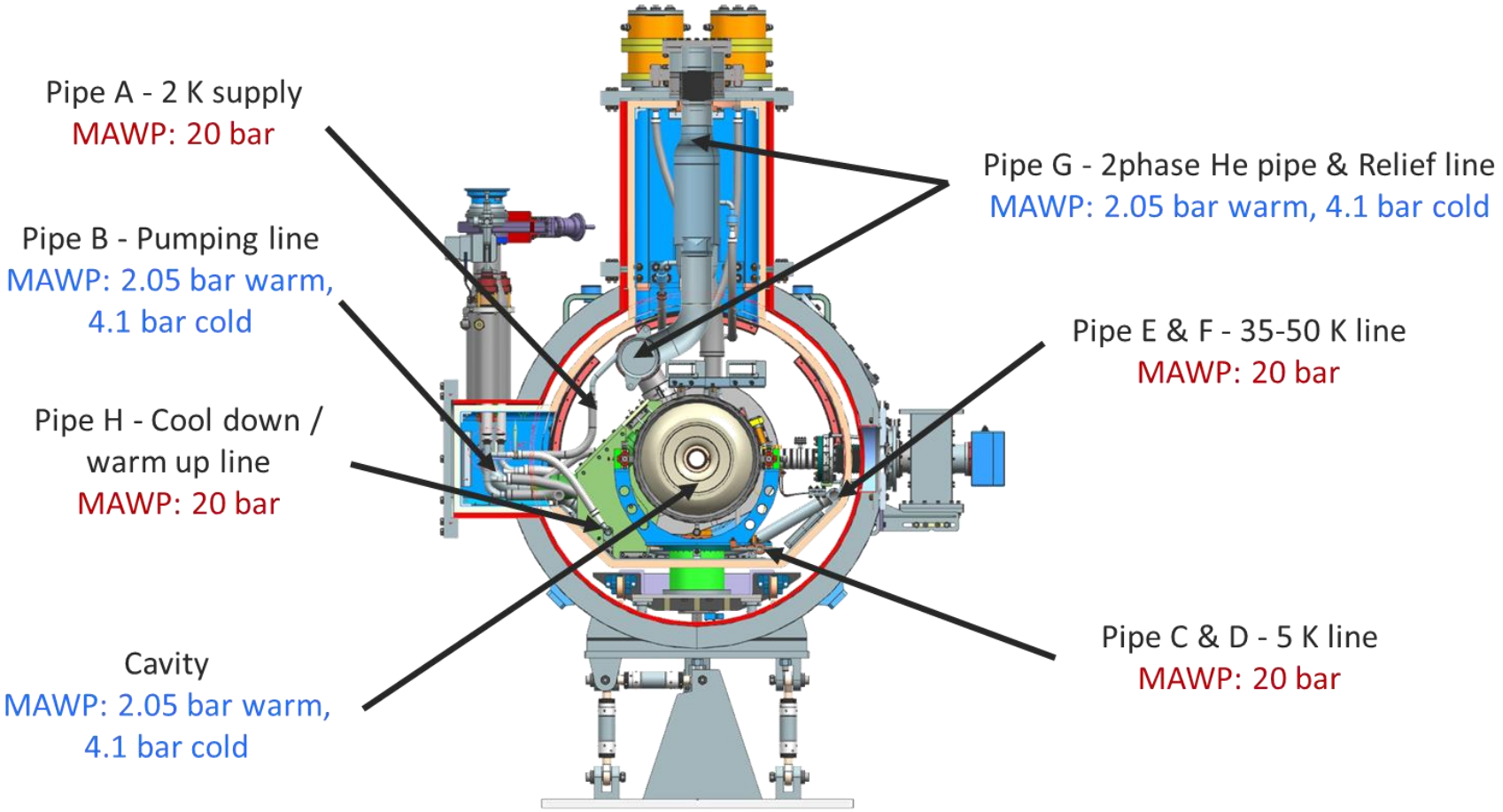




Maximum Allowable Working Pressure - Licensing

Maximum Allowable Working Pressure (MAWP)

- The design pressure of PIP-II cryomodules have been defined by FNAL based on the experience with LCLS II cryomodules.
- Cavity circuit: dual pressures
  - 2.05 bara at warm temperature
  - 4.1 bara at cold



Why two MAWPs for the cavities?

- The use of two Maximum Allowable Working Pressures is based on the enhancements of the material properties of niobium and stainless steel between room temperature and liquid helium temperature.
- In the ASME code, a pressure test is needed unless Xrays are done. Because of the niobium cavity, it is not possible to perform a pressure test at room temperature with a MAWP of 4.1 bar.
- It is not possible to have a unique MAWP of 2.05 bar: the cryogenic lines and the safety devices would have to be bigger, and the 650 MHz cryomodules would have to be redesigned.
- Having a unique MAWP of 4.2 bar would require many Xrays during the assembly process, which could be difficult to overcome, make the assembly process longer and increase the cost.
- The use of dual MAWP allows:
  - For the cavities: to perform only pressure test at room temperature at 2.38 barg (2.05 x 1.15 – MAWP x safety factor).
  - For the piping: to perform test at room temperature using the cold MAWP (test pressure: 4.55 barg – 4.1 x 1.1) on the sub-assemblies whenever it is possible. To perform pressure test at room temperature using the warm MAWP on the closure welds during the assembly of the cryomodule.
- Dual design pressure is only allowed by ASME Section VIII (used for the cavities). This is not possible for the piping (ASME B31.3). A revision of the Fermilab Environment, Safety and Health Manual (FESHM) is being written to allow the use of these dual MAWPs by making reference to the code and to the literature.

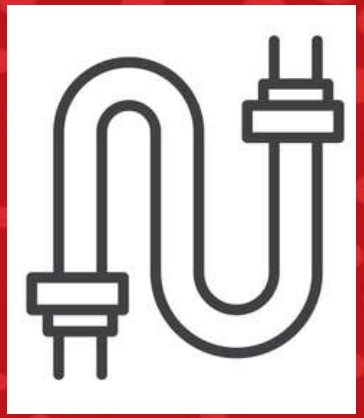
Licensing at CEA Saclay

- Requirement from the CEA Saclay Safety Officer: any pressure equipment in operation shall comply with the European Pressure Equipment Directive (PED) (2014/68/EU).

- CEA PIP-II team is investigating whether it is possible or not to use ASME and Fermilab rules for the manufacturing, assembly and tests of the cryomodules at Saclay .

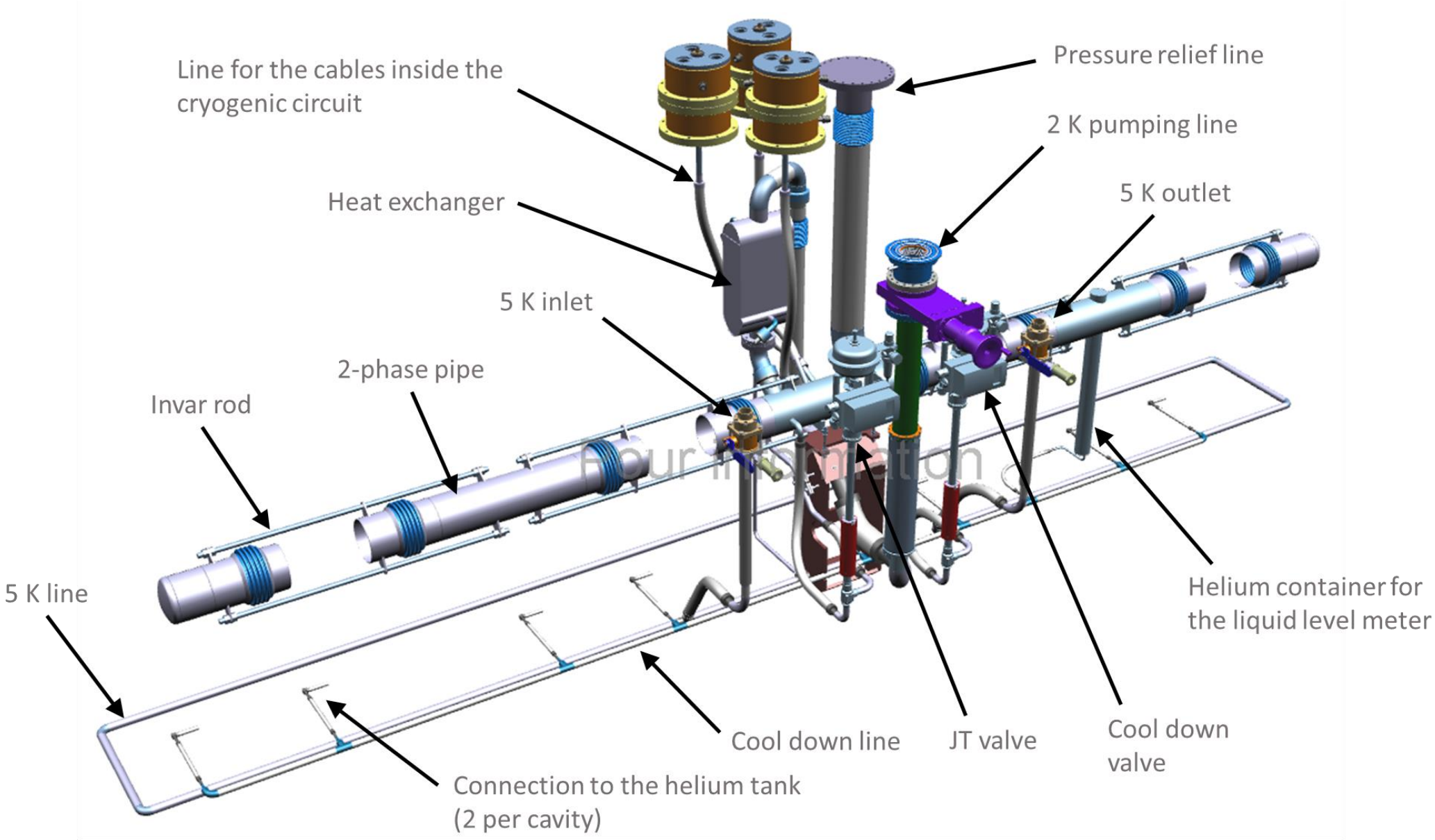
- FNAL PIP-II team asked consultant to provide equivalency & allowance of ASME dual pressure design/rating and PED.

➡ Need to clarify the licensing frame as soon as possible to avoid issues as experienced by CEA on other projects



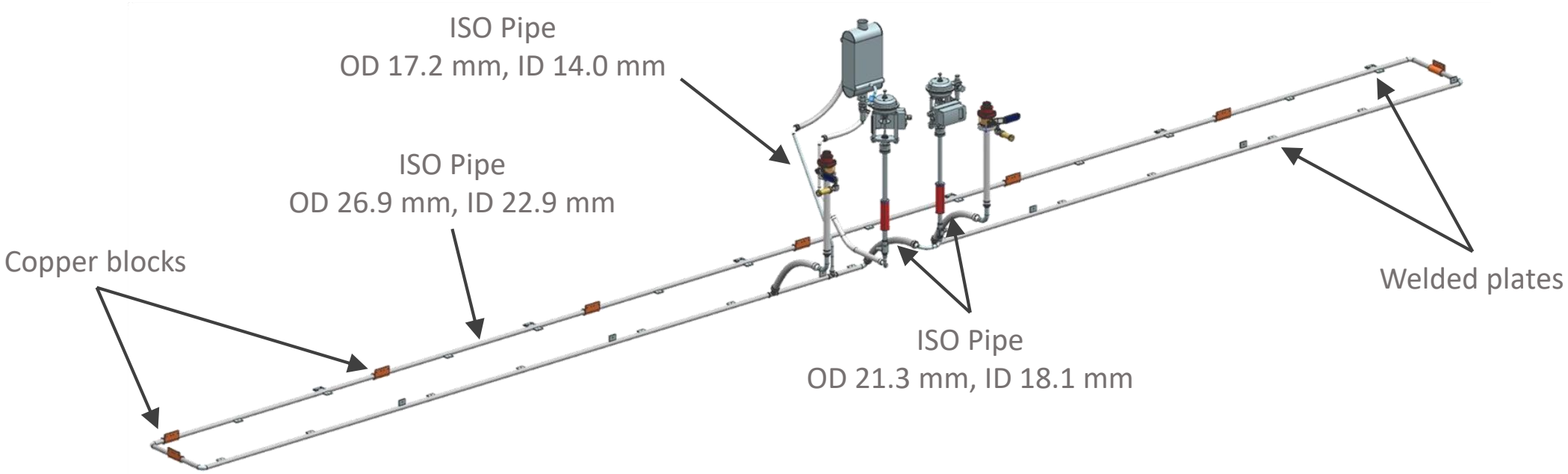
Description of the cryogenic lines

Overview of the cryogenic lines for the cavities



5 K Line

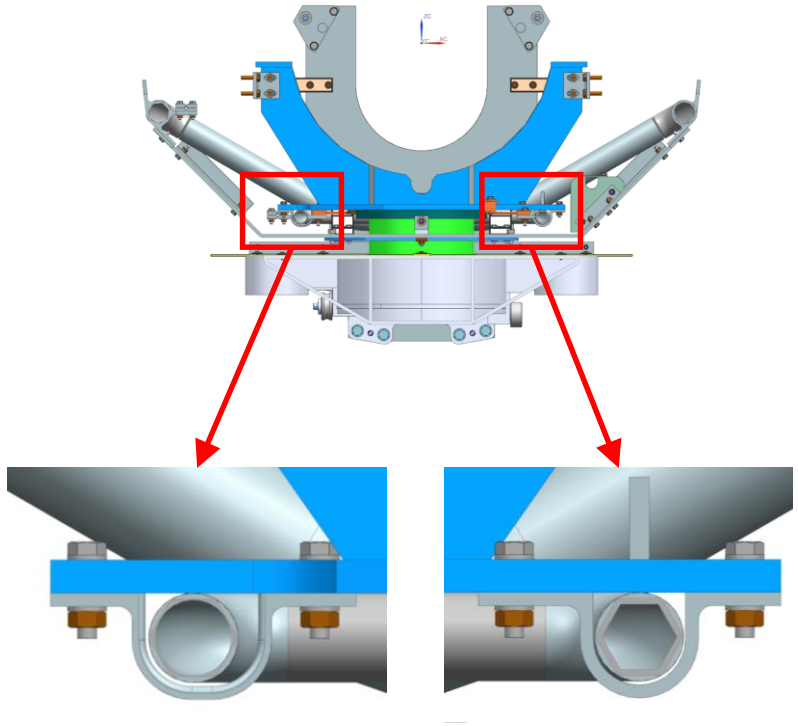
- The 5 K line is used to connect the thermal intercepts. The principle is similar to the HB cryomodule:
  - Copper blocks are brazed to connect the thermal intercepts for the power couplers.
  - Plates are welded to the line to connect the thermal intercepts for the tuner motors, cavity posts and instrumentation.
- The dimensions of the pipes are similar for LB and HB cryomodules.



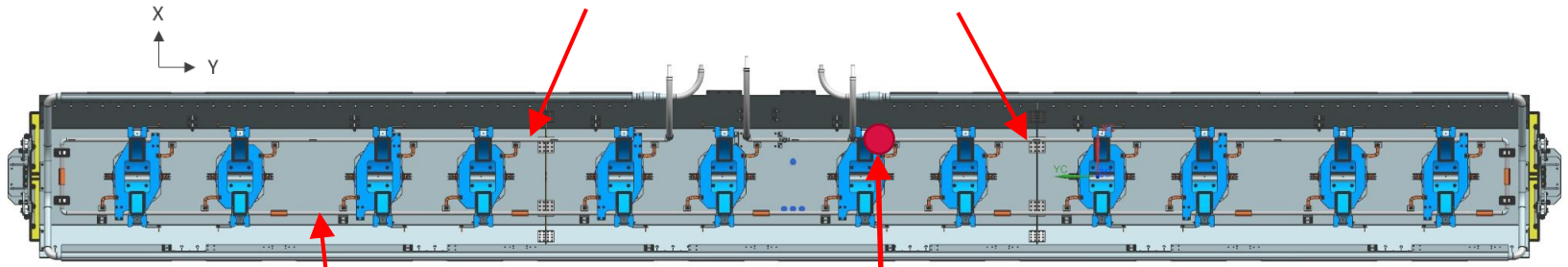
The 5 K line for the HB cryomodule, the copper blocks and plates being not implemented on the LB 3DMU

5 K Line

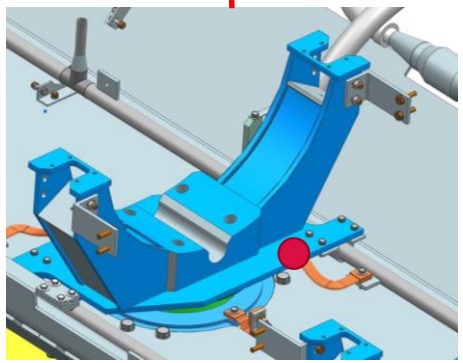
- The 5 K line is supporting by the cavity support posts using brackets.
- The support posts are installed on the strongback and therefore do not move during the cool down → need to give some freedom of motion to deal with the shrinkage of the line



This side of the piping is locked in the X direction and free to move in the Y direction



This side of the piping is free to move in the X and Y directions

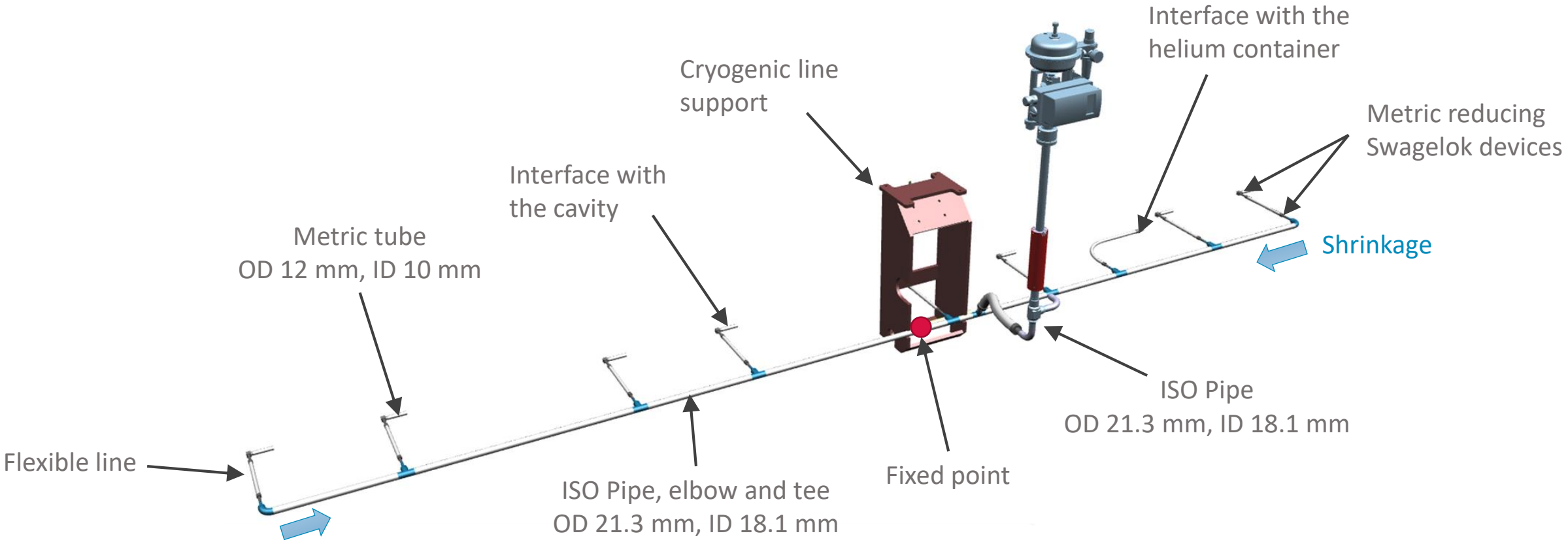


The tube is welded to the bracket to lock it in the X and Y directions. This point does not move during cool down and is the reference.

Figures taken from the presentation "Cryogenic Lines & Heat Loads" given at the Final Design Review of the HB Prototype Cryomodule, July 2020

Cool down / warm up line

- The line is used only during the cool down and warm up of the cryomodule.
- The line is connected at the bottom of the helium tank of the cavity. There are 2 inlets per cavity.
- The dimensions of the pipes are similar for LB and HB cryomodules.
- The pipe is connected to a support that fixes its position during cool down.

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